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Original Article

Canopy Greenfield Detection System and Pesticides Spraying using Drone

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Abstract *- Agriculture is the primary occupation of most of the population of India. The crop yield in agriculture depends on a number of factors, including temperature, humidity, rainfall and the amount of pesticides spread on the farm. The availability of labor and labor cost are major problems nowadays. With the help of emerging technology such as drone spraying, the time, labor cost and amount of pesticide wastage is highly reduced. In this paper, the collection of individual plant crowns, called canopy green fields, is identified using color image processing and a camera mounted on drones (hexa-copter). Over the detected canopy, the pesticides are discharged with appropriate pressure using the sprayer. The multifunctional drone is used for this purpose to test the amphitheatre area of the Sandip Foundation Campus. The experimental result shows that the accurate detection of the canopy is achieved with efficient spraying of pesticides in less time as compared with the traditional manual spraying method.*

Keywords *- Canopy detection, Drone technology, Flight controller, Mission planner software, Pesticide spraying.*

1. Introduction

The Indian economy relies heavily on the agricultural industry, accounting for almost 50% of employment and 17% of the nation's GDP [1]. Pesticide spraying is a crucial aspect of agriculture because it significantly affects crop productivity and effectiveness. When used properly, pesticides can assist farmers in increasing crop yields, improving crop quality, and lowering losses brought on by pests and diseases [2]. According to a study [3], pesticide poisoning is a major occupational hazard for farmers in India, and inhalation of poisonous fumes during pesticide application is one of the common routes of exposure. One more study reported that around 50% of farmers exposed to pesticides had symptoms of pesticide poisoning, including respiratory symptoms such as cough, chest tightness, and shortness of breath [4].

The growing population is the biggest threat to the production and availability of quality food. According to the survey, there are over 815 million chronically hungry individuals in the globe, and 64% of them are in Asia. To overcome this scarcity, food production must be increased to feed the growing population [5]. In addition, it is getting harder and harder to get the essential resources for agricultural production, such as land and water [6], [7]. Therefore, effective use of land and water is essential.

Food availability has been a serious issue in India for many years, especially for marginalized and at-risk groups. Despite tremendous advancements in agricultural production and food delivery networks, India still has difficulties ensuring that its population has enough access to food. The COVID-19 pandemic significantly negatively impacted crop yield and the food supply management chain [8]. Everyone must contribute to achieve the Sustainable Development Goal "Zero Hunger".

Numerous farmers were unable to produce as much because they lacked timely access to critical agricultural resources like labour, seeds, fertilizer and pesticides. When compared to the 11 most technologically advanced nations, many Asian nations are in the emerging stage, where they must deal with difficulties, including a large population and substantially lower agriculture production [9]. The current methods for spraying pesticides and fertilizers take more time and are less effective. Thus, the spraying method needs to advance technologically. [10]. It is incredibly difficult for mainstream farmers to monitor the use of fertilizers, pesticides, and crops during the COVID-19 epidemic period [11].

The emergence of drone technology has opened up a whole new range of possibilities in the agricultural sector. The use of unmanned aerial vehicles (drones) in agriculture is an effective way to address these challenges of farmers mentioned above. Drones can collect accurate data that agronomists, rural experts, and farmers can use to improve their practices and boost yields. [12-14]. Aerial remote sensing is the key technology for Precision Agriculture. This paved the way for developing a low-cost drone with a spraying mechanism that detects the canopy autonomously and sprays only the amount of pesticide required.

This work focuses on developing a multifunctional drone (hexa-copter) embedded with a camera and sprayer. The novelty of the work is to detect the canopy, which is the uppermost portion of the crop, forming a continuous layer of foliage. To detect the canopy, image processing and computer vision algorithms are used to extract the green field part [15, 16]. The processor will detect the canopy and transmit signals to the motor driver to start and stop spraying while the video is being recorded. The pump is used to displace the pesticides stored in the tank with the help of the Li-Po battery. The nozzle is connected to storage tank pipes and converts the pesticides into droplets for spraying. The input current, which is managed by the transmitter, can be changed to alter the pump's flow rate.

The paper's outline is structured as follows: Section II discusses various techniques used for drone spraying. Section III explains the proposed system, followed by experimentation in Section IV. Section V demonstrates the results and discussion of the proposed methodology. The conclusion is drawn in section VI.

2. Related Works

A sprayer drone is made up of a variety of different components, and different techniques are adopted for pesticide spraying. Some of them are highlighted below:

Authors in [17] reviewed agriculture drones, compared different controllers and actuators, and provided the best suitable implementation for the spraying mechanism. Authors in [18] used two agri-drones for spraying pesticides over agricultural land and compared the results in terms of droplet distribution and spraying area covered, which are affected by wind speed. Huang et al. have developed a board sprayer for the UAV named SR200 with a ULV-A+ nozzle, which is implemented for vector control spraying applications [19]. Authors in [20] explained various hardware parts used to assemble drones, especially using the Atmega644 PA processor chip-based KK 2.1.5 flight controller with knob switch durable sprayer nozzle for spraying pesticides in the agriculture sector.

Yallappa et al. [21] evaluated the assembled drone with a sprayer for paddy and groundnut crops and achieved field efficiency of 62.84% and 60 % for these crops, respectively. The spraying mechanism is developed to result in decreased spray liquid loss.

Meivel et al. [22] implemented a quad-copter with an Ardupilot flight controller and captured the green field region over farming land using a RedEdge multispectral camera. The QGIS software is used for image analysis. The GPS module with preloaded GPS coordinates activates the nozzle of the sprayer.

The universal spraying module is used to spray the fertilizers over the desired region. Shaw and Vimalkumar designed [23] the 3-D model of an octocopter using SOLIDWORKS, which is used for pesticide spraying applications. The octocopter is made up of carbon composite material, while the pesticide tank is made of polyethylene. The overall weight of the octocopter is 6 kg, with a payload of 6.75 kg. The total current requirement is about 125 A with 10 minutes of battery drain time.

Vikram Puri et al. investigated various advanced agri-drones viz. Honeycomb AgDrone, DJI Matrice 100 Quadcopter Drone, Agras MG-1- DJI, EBEE SQ- SenseFly, Lancaster 5 Precision Hawk, SOLO AGCO Edition etc. in [24]. Various technical parameters of these drones are discussed with their specified use cases.

Based on the literature review, the green field detection system is developed using a simple field with a view camera, which is more economical than the multispectral camera. Also, the multifunctional drone (hexa-copter) is less weighty at 5 Kg and has a better flight time and payload capacity of 25 Kg.

3. System Development

The proposed system is illustrated in Fig. 1. The Lithium Polymer (Li-Po) rechargeable battery is used as the power source for various electronic devices assembled on drones. Initially, the flight path is mapped in the mission planner software of the drone. The motors as a load and propellers are mechanically linked to each other, and once received, the signal motor is rotated to produce the required thrust. Then, the drone flew over the canopy by following the waypoints of the path set on the mission planner. The drone camera gets activated at the beginning of the drone flight. The camera started detecting the green zone of the canopy using colour image processing. Once the green zone is detected, the flight controller will give the signal. As per the programming instructions, the drone automatically adjusts the speed and a sprayer gets activated. When a non-green zone is detected, the flight controller transmits a signal to the actuator assembly connected to the sprayer. The sprayer then stops spraying till detection of the next green field of the canopy is detected.

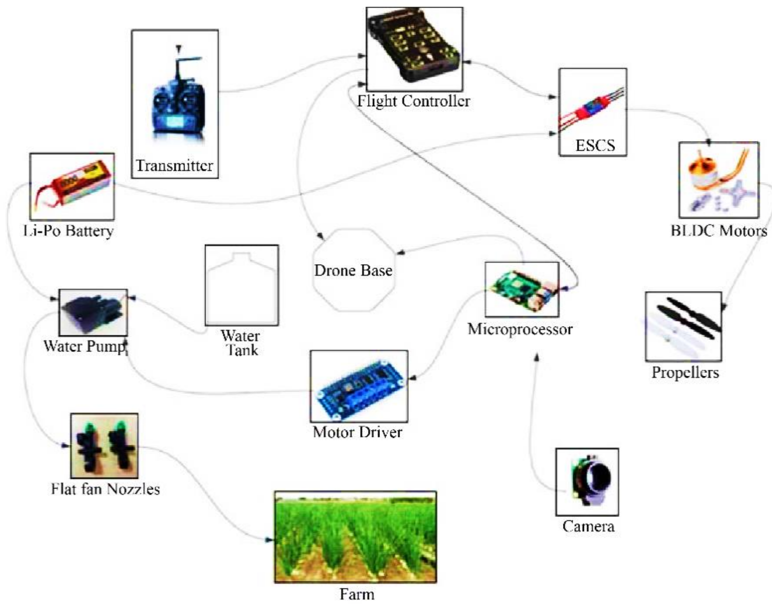

Fig. 1 The schematic view of proposed system

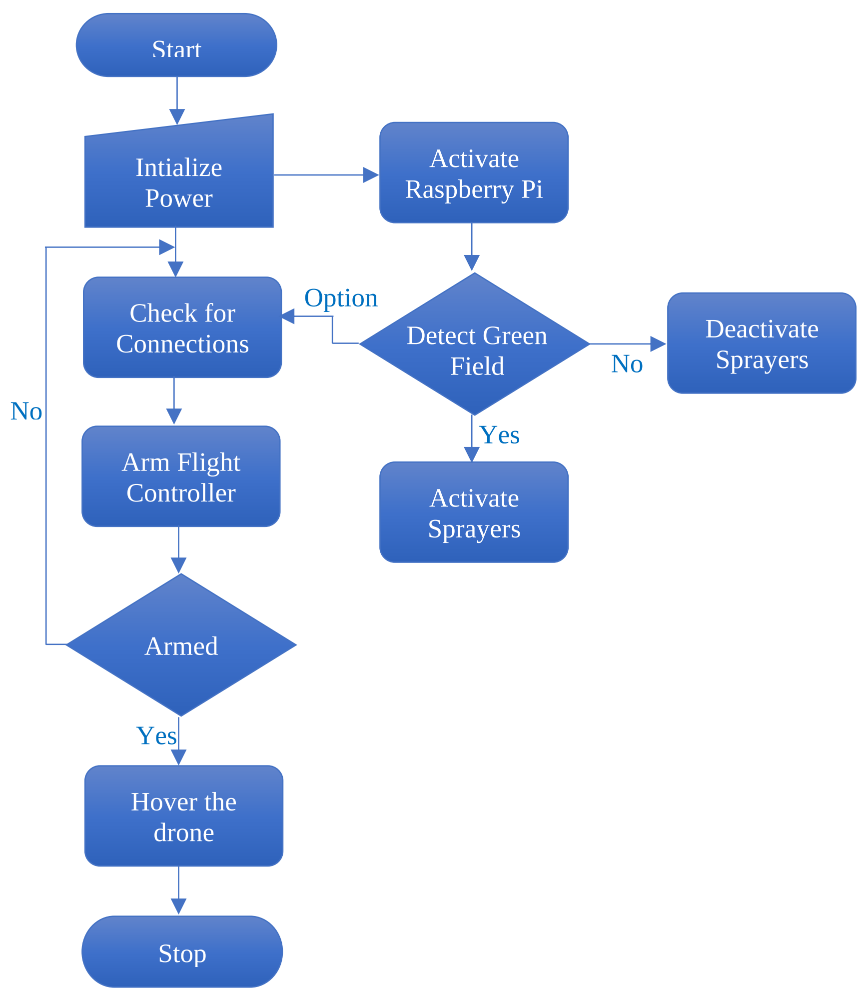

Fig. 2 Workflow of proposed system

The system is separated into two parts: the first is the flying part, and the second is the green field detection part. The flying component includes assembling the drone and operating the flight controller, and the green field detection section includes the operation of the Raspberry Pi. While flying based on data received from the camera, the ARM Cortex-A72 processor detects the canopy as per the image processing algorithm and sprays the appropriate amount of pesticide, as shown in Fig. 2.

The total weight of the drone without any load is 1040 grams while loaded with 2040 grams. The total weight-mounted sprayer is considered when calculating the complete design, along with parameters like payload capacity, supporting frame design, landing gear design, fluid tank design, and motor, battery, propeller, flight controller, transmitter, and receiver selection. The design consideration of the proposed drone is shown in Table 1.

Table 1. Drone design specifications

Sr. No.	Design Parameters	Value
	Hexa-copter details	
1.	Maximum Takeoff Weight	25 Kg
2.	Diagonal Distance	1407 mm
3.	Folded Size (L × W × H) in mm	945 × 848 × 500
4.	Expanded Size (L × W × H) in mm	1945 × 1308 × 500
5.	Working Voltage	50.4 V
6.	Operational Flying Speed	6 m/sec
7.	Maximum Flying Speed	10 m/sec
8.	Maximum Flying Time	10 min
9.	Operating Temperature Range	0 – 50 °C
10.	Transmission Power (EIRP)	2.4 GHz
	Spraying Systems	
1.	Tank Capacity	10 Litre
2.	Material used for tank	Polypropylene
3.	Spray Swath	3 m
4.	Max. Flow Rate	3 Litre/Min
5.	Number of Nozzles	4
	Flight Performance	
1.	Maximum tilt angle	30 degrees
2.	Maximum yaw speed	150degrees/sec
3.	Maximum vertical speed	6 m/sec
	Remote Controller	
1.	Maximum flight distance allowed	1 km
2.	Frequency Band	2.4 – 2.483 GHz
3.	Battery	Li-Po
4.	Charging Port	Micro-USB (5V/2A)
5.	Antenna Gain	5 dBi

Apart from technical specifications, our assembled drone-mounted sprayer is committed to providing the best results for the weather conditions:

(i) The wind speed should be less than or equal to 7 kmph.
(ii) The outside Air Temperature should be less than or equal to 350 °C.
(iii) The relative humidity should be more than or equal to the 50 %.

The Power capacity system is 16000 mAh and has up to 200 life cycles. The flight controller is the main device used to control the drone. Our assembled drone (hexacopter) mounted sprayer and camera with PIXHAWK flight controller are shown in Fig. 3.

Fig. 3 Sample assembled drone with mounted sprayer and camera

4. Experimentation

The experimentation is carried out using Open CV with support for Python in the Raspberry Pi (32-bit) Lite operating system. The communication between the Pixhawk flight controller and Raspberry Pi (RPI) is done via MAV Link. The Drone Kit Python dependencies are installed in RPI.

The Pixhawk provided commands for MAV Link, which was received via the telemetry port to verify that the Raspberry Pi and the ground station (i.e. Mission planner) are connected. The Mission Planner software is connected with RPI and is shown in Fig. 4.

Fig. 4 Connecting mission planner software with Raspberry Pi

Fig. 5 Mission planner showing the latitude and longitude for canopy detection

Fig. 6 Flight plan using mission planner

The flight plan must be decided prior to capturing the images with a drone camera and spraying the pesticides using the flat nozzle. The multifunctional drone is tested on the amphitheatre area of the Sandip Foundation campus to be used for this purpose, as shown in Fig. 5.

The waypoint (as shown in green colour) is mapped such that it covers green and non-green regions to test the algorithm for canopy detection, as shown in Fig. 6.

The flight plan with waypoint, latitude, longitude and altitude is shown in Table 2.

Table 2. Drone flight plan

Sr. No.	Mission Plan Status	Delay#	Latitude	Longitude	Altitude (in meter)
1.	Takeoff	00	19.9652490	73.6678362	00
2.	Waypoint with Delay	01	19.9650624	73.6677960	05
3.	Waypoint with Delay	01	19.9649440	73.6678308	05
4.	Waypoint with Delay	01	19.9646944	73.6681017	05
5.	Waypoint with Delay	01	19.9646414	73.6683726	05
6.	Return To Launch	00	19.9648078	73.6682305	00

Fig. 7 Canopy detection using drone

1 second to the delay at each waypoint, the delay time will be 65.535 seconds.

A camera connected to Raspberry Pi is placed on a drone for crop monitoring, and it is capable of taking live images at a resolution of 1920 × 1080 pixels. This enables time series analysis of the recorded video data at the maximum video quality of 4/60 fps (Frames per second). The canopy detection based on green field detection using an image processing algorithm is performed in Sandip Foundation Campus at Amphitheatre. The flying drone (without a spraying module) in the Sandip Foundation campus is shown in Fig. 7.

Canopy covers denser vegetation part of plants and lesser visible soil. The vegetation part is captured by extracting the green colour region of interest. The flying drone captured video of the region of interest. The RGB image is converted to HSV format to detect a green colour. The minimum and maximum colour values (i.e., hue, saturation, value) are obtained to locate the mask for green colour. The two arrays of lower and upper, according to the maximum and minimum values, are defined, and values are put in range to get an image containing masking. After this, bitwise AND-ing on each pixel is performed, and finally, the object of the frame containing that pixel, which has green colour values, is obtained. The algorithm for detecting green field region is given in Algorithm 1.

Algorithm 1: Detection of Green Field region

Input: Captured Image using a camera embedded in a drone
1. Convert the RGB colour space to HSV colour space.
2. Set range (upper and lower threshold values) for each colour separately, viz. for Red, Green and Blue.
3. Dilate the image using the kernel to create a mask for a specific Green colour.
4. Use the Bitwise AND operator between the image captured and the green colour mask to detect the colour.
5. Use the same operator to distinguish non-green colours from black colour.

Output: Detected Greenfield region from the captured image.

5. Results and Discussions

The flying drone captured the canopy image at three different places in the Amphitheatre, shown in Fig. 8-10. The detected canopy image is sent to Mission Planner software to locate the exact longitude and latitude of the region.

Fig. 8 Near A-Building: Original image (Left) and canopy detected image (Right)

Fig. 9 Near B-Building: Original image (Left) and canopy detected image (Right)

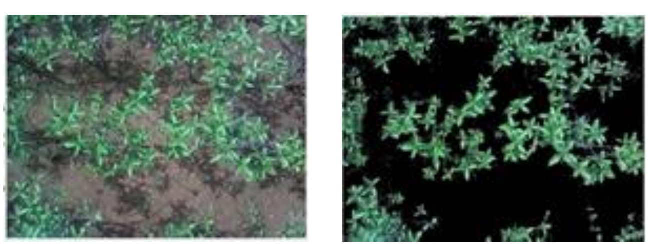

Fig. 10 Near C-Building: Original image (Left) and canopy detected image (Right)

Based on it, the RPI sends the command to the flight controller to wait above the canopy region. The RPI operate the motor control driver, which executes the pesticide tank to spray through the nozzle.

The Normalized Difference Vegetation Index (NDVI) is computed as given in Equation (1).

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})} \quad (1)$$

The NDVI is obtained from drone images captured with the help of OpenCV software, and Python is used for programming. The value is normalized to visualize the image in the range of 0 to 255 (grayscale). The green region is segmented using the predefined threshold value of 0.2.

Although the flight controller is not directly controlled using Open CV and Python, middleware plays a vital role in communication with the flight controller using a protocol such as MAVLink. Based on the image analysis carried out, the MAV link is used to send the command to the flight controller for initialization of the spraying operation over the green field region.

The spraying efficiency and percentage of waste pesticide are computed using our method and compared with existing resources required by tractor-mounted spraying and labour-based spraying mechanisms. It are presented in Table 3 (at the end of the paper). Table 3 provides the comparison of the proposed method with the existing method, viz. manual and tractor. The efficiency of spraying for tractor-based methods is calculated by attaching litmus paper to check the spraying area, whereas in the case of manual spraying, the details are taken from the farmers. The findings showed that 10 minutes of drone flying time could be used to spray the pesticide, resulting in a 65% reduction in labour costs, an 85% reduction in spraying time, and a 50% reduction in insecticide usage.

6. Conclusion

This paper investigates the different drone specifications designed for pesticide/insecticide spraying on farming land. After that, the hexacopter drone is designed to have 6 Kg weight, 25 Kg payload capacity and 10 minutes of flight time. With the help of colour image processing techniques, green field detection is achieved, representing the crop canopy in less than one minute duration.

Table 3. Computation of spraying efficiency and percentage of pesticide wastage

Sr.No.	Methods	Tank Capacity	Rate/Acre	Work Efficiency	Refueling time	Wastage
1	Tractor	200-litre drum	5000rs/Acre	1 acre/35min	30 minutes	40%
2	Manual	15 litre	300rs/Acre	1 acre/55 min	15 minutes	50%
3	**Drone**	**10 litre/ 16 litre / 30 litre**	**800rs/Acre**	**1 acre /7min**	**10 minutes**	**10%**

The Mission Planner simulation software is used to locate detected canopy for spraying purposes. The designed multifunctional drone is equipped with a pesticide sprayer, which requires 6-7 minutes (overall) time to spray a one-acre area uniformly with less pesticide loss.

In future, the surveillance function of this drone will be utilized to evaluate plant insect attacks. Additionally, this drone will be utilized to spray disinfecting materials over buildings and densely populated areas. The dataset of drone images and video frames can be developed and analyzed to predict better agriculture produce and crop disease forecasting using Artificial Intelligence and Machine Learning based algorithms. With this, farmers can take corrective action and avoid probable loss in agriculture production.

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